WET WEATHER STRATEGY FOR THE WOODWARD WWTP – DEVELOPMENT OF A COMPREHENSIVE PROCESS MODEL

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ABSTRACT

The City of Hamilton is reviewing a number of options to handle wet weather flows in its sewer and treatment system. Optimizing the operation of a number of combined sewer overflow storage tanks and the wastewater treatment plant is proposed as a means of handling the greatest wet weather flows in the system. The goal being to provide the maximum level of treatment to the greatest amount of wet weather flows. This could mean full secondary treatment for elevated flows, but also pre-treatment and primary treatment of even greater volumes of wet weather flow.

This paper reviews a process used to develop a comprehensive model of the Woodward Avenue wastewater treatment plant (WWTP) to review wet weather strategies at the plant in conjunction with the operation of the sewer system. The comprehensive process model will be used to identify the optimal operating mode at the plant for a variety of conditions in the system.

KEY WORDS

Wet Weather Strategies, Modelling, Optimization

INTRODUCTION

The City of Hamilton (City) has acted over the last few years to manage elevated flows into their sewer system and wastewater treatment plant (WWTP). A total of five combined sewer overflow (CSO) storage facilities have been constructed providing 193,000 m^3 of storage volume. In addition, the capacity at the Woodward Avenue WWTP has been expanded to handle higher flows, including expansion of the primary clarifier capacity, separate mechanical thickening of biological solids (increases primary throughput and reduces solids recycle streams), upgraded secondary processes (aeration and final clarifier retro-fits) and upgraded headworks. The result has been the capability to store and potentially treat a greater portion of the wet weather flows at the WWTP.

The objectives of this current project are to determine the wet weather capacity of the upgraded Woodward Avenue WWTP and provide operational guidance on how to reach its potential wet weather capacity. The final goal being to develop a capital and operating plan to increase the capacity of the plant to treat wet weather flow. Funding for this project was provided by the City and Environment Canada through its Great Lakes Sustainability Fund.

To undertake this project, as the plant has ongoing upgrade projects underway, and to predict performance prior to handling these flows at the plant, a process modeling approach was proposed. This paper presents the comprehensive model development including plant characterization, intensive sampling and monitoring, model calibration and evaluation of plant capacity. Process modeling provided the unique ability to model numerous control strategies in conjunction with the City's CSO storage facilities. The plant also allows for partial treatment of wet weather flows increasing the complexity of determining the optimal strategy – making modeling a useful tool.

BACKGROUND

The Woodward Avenue WWTP has an average design capacity of 409 MLD and is a complex interconnected plant. Under extreme weather conditions the plant has the storage capacity at the five CSO storage facilities and bypass capability at these locations and at the plant. The WWTP also can bypass flows after pre-treatment and enhanced primary treatment. The capability to partially treat wet weather flows at the plant will be enhanced in the future with additional pre-treatment capacity. Part of the secondary process has the capacity of operating under step-feed conditions. The solids handling processes include mechanical WAS thickening, digestion, centrifuge dewatering, and belt press dewatering with associated recycles to the liquid train. All these aspects of the facility need to be characterized by the process model.

A process model of the plant needs to have the ability to characterize the main unit processes and the interconnection between, so that accurate predictions of the capacity under various conditions can be made.

METHOD

A step-wise approach was used to develop a wet weather strategy for the Woodward Avenue WWTP. The steps included model layout, calibration, verification and model usage. A major component of the model calibration and verification was the development of a comprehensive sampling program at the plant.

A process model was developed using GPS-X^{TM} (see Figure 1) such that all the processes, including the solids handling processes, could be characterized by the model – including the capability to partially treat influent under various conditions[1,2]. To fully utilize the simulator's capability an intensive sampling program was undertaken at the plant, including:

- Increased sampling locations (liquid and solids trains)
- Increased analysis (additional parameters including soluble fractions, COD etc.)
- Dynamic sampling (hourly sampling for dry and wet weather periods)

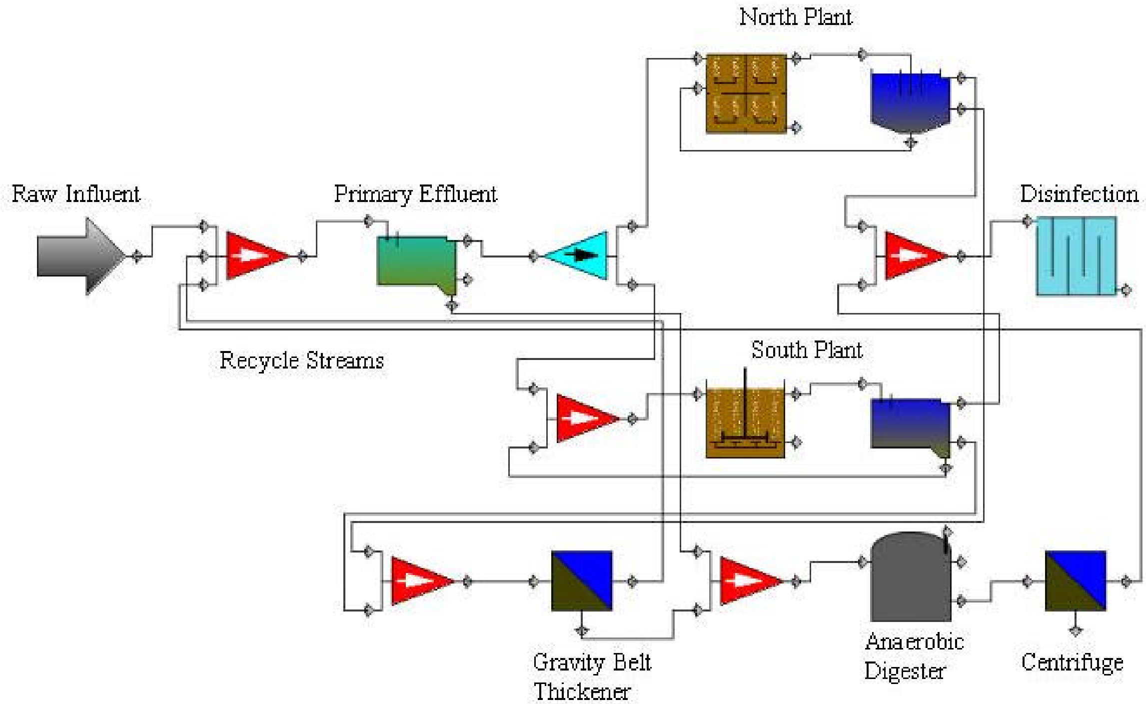

FIGURE 1 – GPS-X LAYOUT OF WOODWARD AVENUE WWTP INCLUDING SOLIDS HANDLING

- Temporary flow monitoring of various streams (including solids recycle streams and bypasses)

Figure 2 shows the thirteen sampling locations used during the intensive sampling period. Samplers were located on the secondary effluents of the North and South secondary plants, since the normal effluent sampling does not differentiate between the two secondary plants and to optimize the facility each plant needs to be modeled separately. Solids handling recycle streams were also sampled and flow monitored.

Samples were taken using automatic samplers for either discrete or composite samples, depending on the sampling program. Flows were measured using plant verified flow meters where possible, and complemented with potable flow meters for the secondary bypass and solids handling recycles.

Once the process model was calibrated and verified, it was used to evaluate the plant's performance under various flows at a variety of process operating conditions and simulated with new unit processes and upgrades in place.

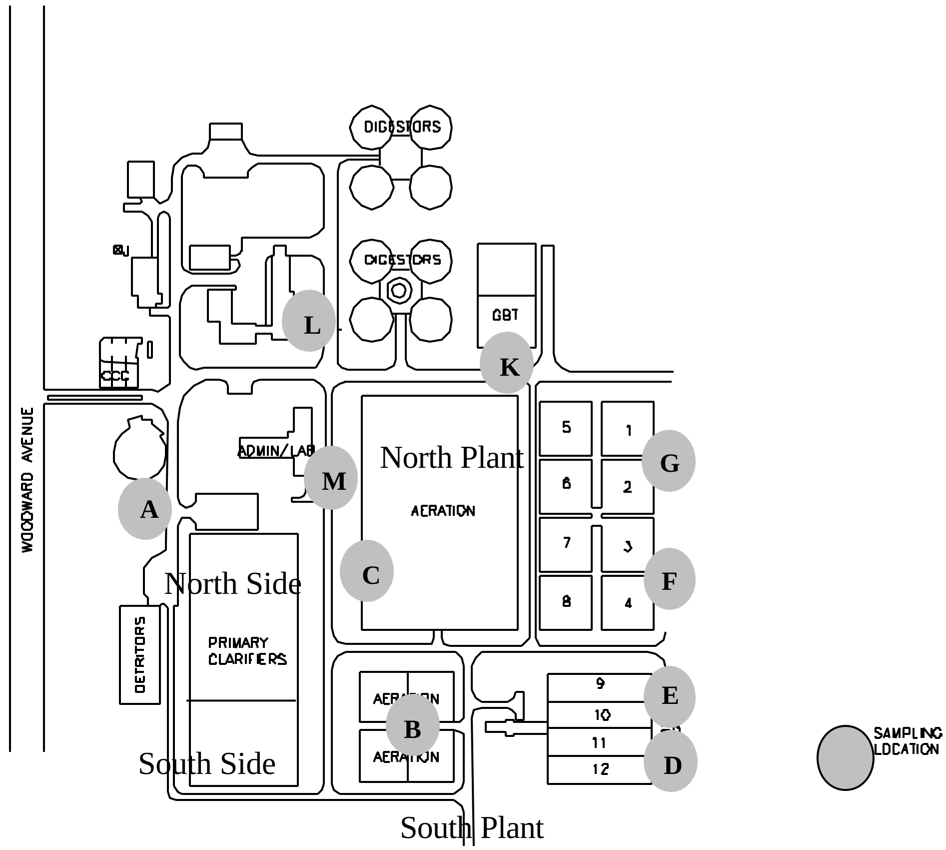

FIGURE 2 – INTENSIVE SAMPLING LOCATIONS

RESULTS

The following presents the sampling, modeling, and model usage results undertaken to date.

Calibration and Verification

Dynamic sampling was conducted during a dry weather and wet weather period to provide a comprehensive database for calibrating the complex plant model. Flows for the two periods are shown in Figure 3 with the rainfall for the wet weather period. The results indicate that two unique sampling periods were identified. The dry weather period had an average influent flow of 280 MLD, while the wet weather period averaged 330 MLD. Dry weather flows ranged from approximately 150 to 350 MLD, while for the wet weather period the maximum flow increased to 550 MLD. Due to retrofit work being conducted in the North plant these events involved use of the CSO storage facilities and secondary bypass at the plant.

Figure 4 shows the influent and primary effluent concentrations for the wet weather period. The influent varies greatly, indicating a potential "first-flush" effect. The primary effluent remains relatively constant for much of the event due to its buffering capacity.

Major concerns included:

- Flow splits - metering problems were identified in the data
- Recycle ratios and mass balances - determined errors in RAS flows in one plant
- Recycle characterization – sampling and monitoring recycles identified one measurement was in error, redundant measurements permitted corrections

Calibration of the effluent performance was conducted using the intensive steady-state period and the wet weather events. Figure 5 shows a month-long period for the effluent COD and soluble COD from the secondary clarifiers, indicating a close correlation to the data. An enhanced database and accurate characterization of all processes facilitated an accurate calibration providing a flexible tool for predicting the performance under varying operations.

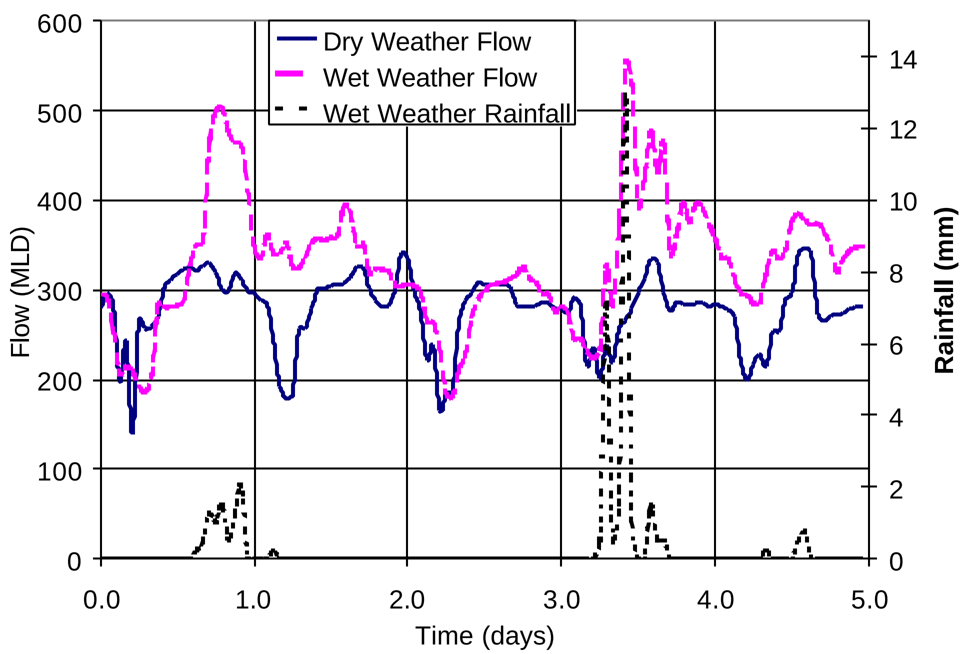

FIGURE 3 –FLOWS DURING DRY AND WET WEATHER INTENSIVE SAMPLING PERIODS

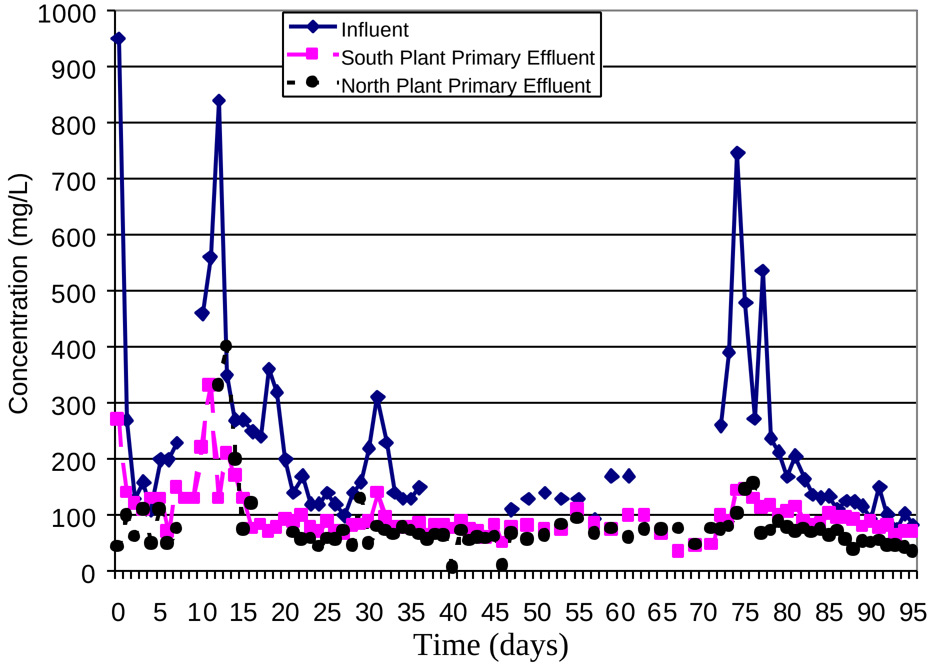

FIGURE 4 – INFLUENT AND PRIMARY EFFLUENT SS DURING WET WEATHER EVENT

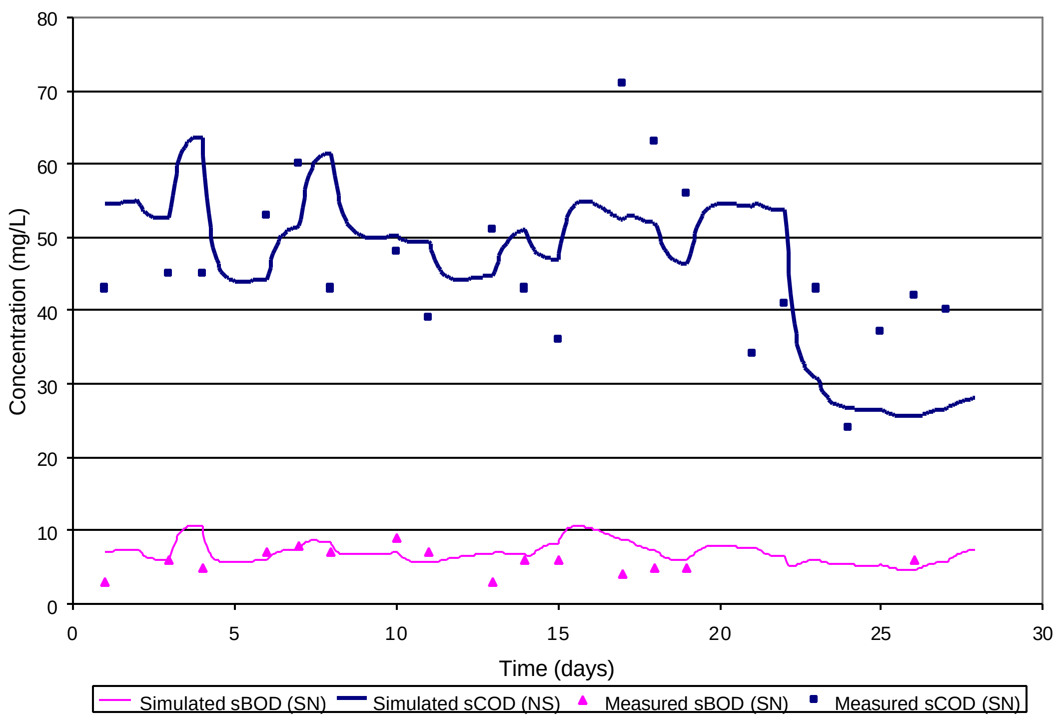

FIGURE 5 – ACTUAL AND SIMULATED SECONDARY EFFLUENT COD CONCENTRATIONS

Wet Weather Strategy

Control of collection system and the wastewater plant needs to be optimized to make the most of available storage, processes and capacities. Control options in the collection system include:

- Storage, the existing system has five CSO storage tanks, others are in the planning stages
- Satellite Treatment, various degrees of treatment are possible at remote sites from the plant to treatment wet weather flows from screen, primary treatment and/or equivalent (e.g. high-rate separators) and disinfection. An excellent example of complete satellite treatment of CSOs is the Columbus, Georgia demonstration site with screening, enhanced vortex treatment, filtration and UV disinfection[3].

Control options at the treatment plant for elevated flows are a long-list of process operational/process upgrades and selective expansions. Some are existing some will be evaluated. Process operational/process upgrade options include:

- Control modifications, utilizing aeration system step-feed, aeration system anoxic zones and recycles, and wasting strategies
- De-bottlenecking, controlling and managing settleability, specific hydraulic capacities, solid handling, and aeration capacity
- Sidestream management, minimizing loadings from sidestreams and optimizing the location of re-introduction of these streams

Selective expansion is also a means of significantly increasing the wet weather capacity of a plant. Selective expansion options for the Woodward Avenue WWTP include additional:

- Preliminary treatment, expansion of screening and grit removal, already ongoing with new screening and vortex grit removal facilities[4]
- Primary or equalivent treatment, expansion of primary tanks (already undertaken and complimented with ending biological sludge co-thickening), chemical (metal and/or polymer) augmentation, and separate wet-weather facilities (similar to satellite treatment but at WWTP)
- Secondary treatment, expansion of aeration and clarification capacity, addition of fixed film support media, wet weather secondary clarifier augmentation
- Dual-purpose tertiary treatment, for all or part of the plant capacity

Model Usage

Initial use of the calibrated and verified model has been made to estimate the peak instantaneous process capacities (i.e. the primary and secondary treatment capacities) of the various unit processes under a variety of operating conditions.

To determine these peak process capacities, the calibrated GPS-X model of the Woodward facility was used. In both analyses, the objective was not to determine a sustained high flow, but a short term peak capacity. To do this, an artificial storm event was used. The storm event is based on:

- Existing average influent concentrations
- Sustained average influent flow rate before the event occurs based on existing average flows (280 MLD)
- The storm flow event is 2-hours in duration
- Event peak flow was tested at increments of 50 MLD above average influent flow (e.g., 330, 380, 430, etc. MLD).

A sensitivity analysis of the primary clarifiers to a peak influent flow was completed to examine primary clarifier failure under high loads. It is difficult to define failure of the primaries under peak conditions. MOE Procedure F-5-5 requires an annual average wet weather solids removal of 50% during a typical year. Since this is an annual average, it suggests that instantaneous removal can be significantly lower than 50% removal. Instead of pre-selecting a failure point for the primaries, successive simulations were completed of peak flows up to 1300 MLD for a 2-hour duration.

Figure 6 shows the dynamic results of one of these simulations (peak flow of 680 MLD). From each of these simulations, the lowest removal efficiency was identified (e.g., in Figure 6, the minimum removal efficiency on the South side is 20%, and 38% in the North side at a total influent flow of 680 MLD). The split between the North and South side for these simulations is 60% of the flow to the North side, and 40% of the flow to the South side. The results could be equalized (i.e., North and South removal efficiencies made the same) by changing the North/South flow split. But the peak flow can be identified for the North and South from separate runs.

From the results typified in Figure 6, the solids removals at various peak flows were first analyzed based on the existing primary sludge settleability (based on the calibration data). These results are shown in Figure 7.

At existing average total influent flow (280 MLD), the removal efficiencies are:

- North side (at 168 MLD North side flow) – 60% solids removal
- South side (at 112 MLD South side flow) – 40% solids removal

According to the model, the South side totally fails at total influent flows above 1000 MLD (400 MLD to the South side) and removals drop significantly. And the system as a whole (i.e. blended average) removes less than 25% of the solids entering the primary system when the total influent flow is greater than 800 MLD.

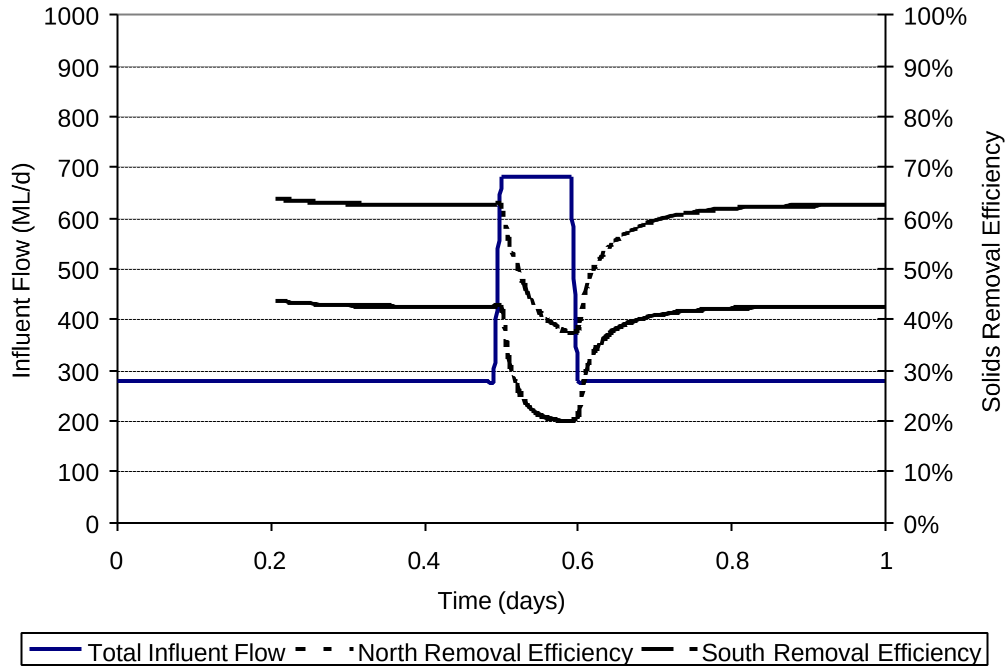

FIGURE 6 – EXAMPLE OF DYNAMIC EVENT AND RESPONSE OF PRIMARY CLARIFIERS

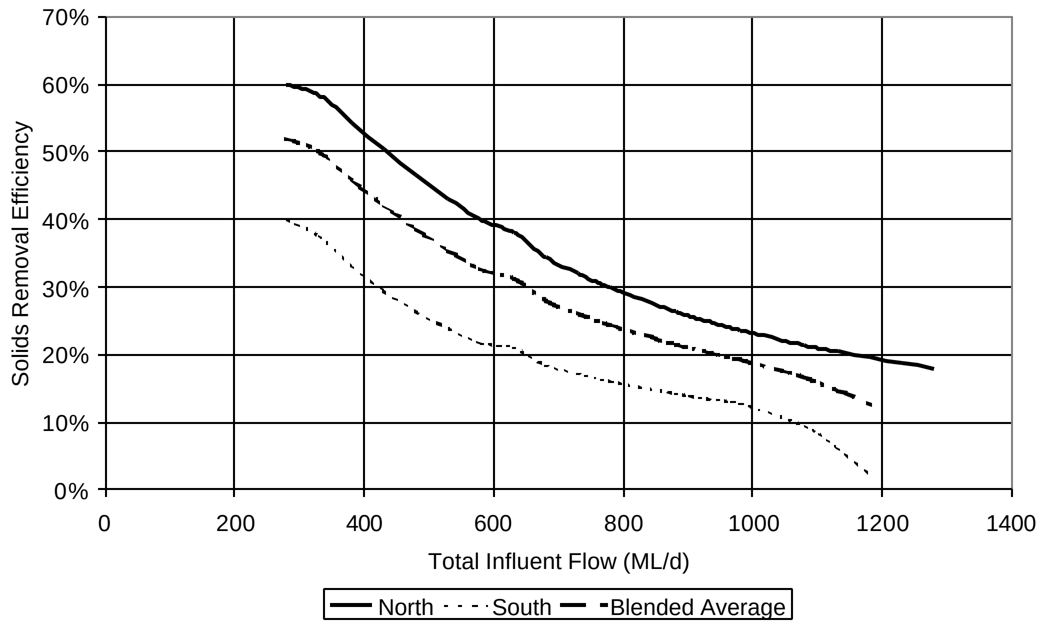

FIGURE 7 – PRIMARY CLARIFIER REMOVAL EFFICIENCY AT EXISTING RAW SLUDGE SETTLEABILITY.

Further examination of the primary system was also completed assuming better raw sludge settleability. This was necessary since one of the options for wet weather flow control is to use chemical-assisted primary settling. Without further analysis and testing of the raw sludge, we can only presume what the improved settleability would be with settling aids. As a first step, the settleability parameters were set to values that are typical of raw sludge settleability that Hydromantis has encountered in other modelling projects. At a total influent flow rate of 1300 MLD, a reasonable system-wide solids removal of over 30% is still attainable. This would include 780 MLD to the North side and 520 MLD to the South side. Changing the flow split between the North and South side could help to equalize the difference between north and south primary performance at these high flows.

Further model runs are planned to equalize North and South side primary clarifier performance – and to examine the effects of further improvements to primary performance through chemical settling aids. But it appears from the initial model simulations, that total high flows to the primary approaching the pumping capacity of the headworks pumping station (1380 MLD) should be treatable to a modest extent (in the order of 30% solids removal) for short periods of time. This would be equal to a surface overflow rate of 5.4 m/h – which is marginally greater than the design peak overflow rates for primary systems that do not have WAS co-thickening (i.e., MOE design guidelines from 3.3 to 5 m/h). Historically the plant has operated the primary clarifiers at significantly lower overflow rates (approx 1.8 m/h based on daily maximum flow), due to ongoing primary clarifier upgrades, pretreatment system limitations and hydraulic issues.

Therefore, an initial peak instantaneous primary process capacity of 1380 MLD is expected under optimal conditions. The hydraulic capacity will be evaluated at this level to determine whether process performance or hydraulics limits capacity of the primaries. In addition, performance during longer wet weather events will be evaluated.

A similar approach to that used in the primary peak capacity analysis was used to analyze the capacity of the secondary system (i.e., 2 hour storm flow). The peak capacity was defined as the flow at which the final effluent solids concentration is approximately 25 mg/L. The Certificate of Approval (C of A) “not to exceed” limit is 25 mg/L based on a monthly average. Therefore, is reasonable to exceed this limit periodically, as long as the monthly average does not exceed 25 mg/L. Initial simulations were based on the settleability noted during the sampling period (i.e., SVI = 250 mL/g).

The South plant exceeds 25 mg/L when the total influent flow is approximately 350 MLD (or 140 MLD for South plant flow). The North plant exceeds 25 mg/L when the total influent flow is approximately 550 MLD (or 330 MLD for North plant flow). Summing up the North and South side flows when each exceed 25 mg/L gives a total secondary peak process capacity of 470 MLD. This result assumes 70% of the total influent flow is directed to the North plant. It also assumes the poor sludge settleability that was evident during the summer 2001 sampling program.

Since the purpose of the wet weather strategy is to determine what the "likely" peak flow is that will be treatable in the secondary system, a second analysis was completed assuming improved settleability or a lower SVI (i.e. 100 mL/g). Therefore, these simulations assume that the plant will eventually be able to improve the sludge settleability in the secondary clarifiers. Lower SVIs have been evident at the plant since mid-December and it is expected that current upgrades (e.g. anoxic zones, aeration upgrade and improved RAS operation) will allow for better control of settleability at the plant. The SVI from December 15, 2001 to January 18, 2002 averaged 120 mL/g in each plant. Therefore, an improved SVI is possible and is a goal for optimized performance at the plant.

The results of this analysis are shown in Figure 8. Figure 8 assumes a constant 60/40 flow split between the North and South plants and the flow value is shown as the total flows through the secondary processes.

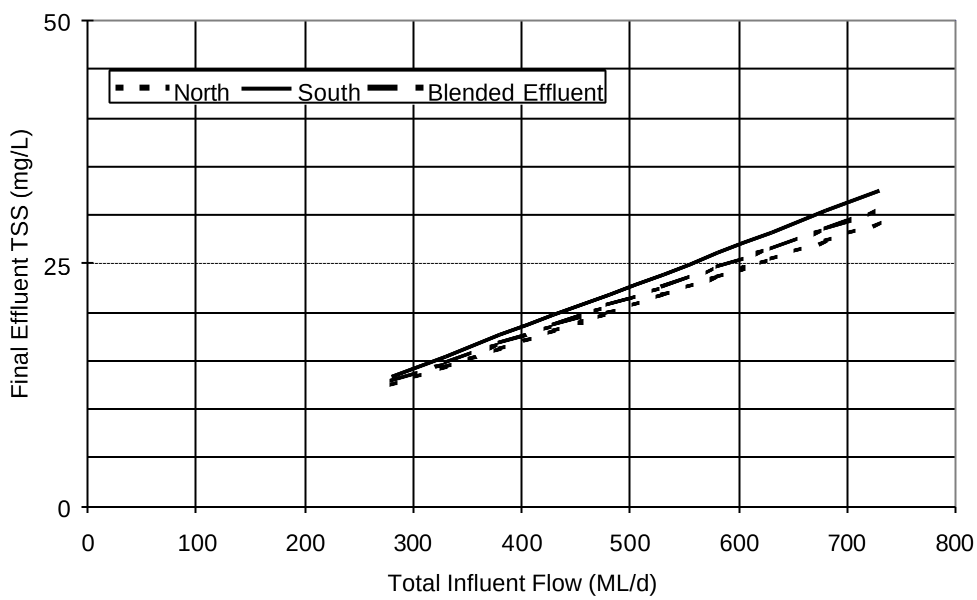

FIGURE 8 – PEAK FINAL EFFLUENT CONCENTRATION WITH IMPROVED SECONDARY SLUDGE SETTLEABILITY (SVI = 100 ML/G)

The South plant exceeds 25 mg/L when the total influent flow is approximately 550 MLD (or 220 MLD for South plant flow). The North plant exceeds 25 mg/L when the total influent flow is approximately 620 MLD (or 370 MLD for north side flow). Summing up the North and South plant flows when each exceed 25 mg/L give us a total secondary peak process capacity of 590 MLD. But it is interesting to note that if the C of A peak flow (614 MLD) is put through the plant, the model predicts a combined effluent TSS of less than 27 mg/L. Therefore, it seems reasonable to suggest that the peak secondary capacity can be at least that of the C of A, or 614 MLD.

CONCLUSIONS

The goal of optimizing the Woodward WWTP is ongoing and the process is being assisted using a modeling approach. The modeling approach allowed for the evaluation of current and future upgrades at the plant and the ability to simulate various wet weather scenarios. Calibration and verification of the model was undertaken by conducting an intensive sampling and monitoring program, including discrete dry and wet weather sampling/monitoring. The resulting model accurately simulates the WWTP including solids handling processes and recycle streams.

Definitive peak process capacity limits (e.g., capacity limitation not including hydraulic limitations) for the primary and secondary systems cannot be determined. Procedure F-5-5 guidelines for the primaries are for long-term performance. Also the C of A final effluent limits are based on monthly averages. However, examining the sensitivity of the response of the primary and secondary system to peak influent flow rates can provide some insight into likely peak process capacity limitations.

The primary system appears to be able to modestly treat short-term peak flow in excess of 1300 MLD assuming modest improvements in settleability – such as might be feasible through settling aids.

The secondary system was evaluated based on an effluent suspended solids limit of 25 mg/L. Assuming improved sludge settleability, as is obtained in typical activated sludge plants, the model predicts at peak secondary capacity of 590 MLD. However, if we relax the 25 mg/L limit (since we are dealing with peak capacity, and the 25 mg/L value is based on a monthly average), it seems reasonable to use a peak secondary capacity of at least 614 MLD, as specified in the C of A.

Additional modeling will be undertaken for this project to evaluate expected storm events under a variety of collection system operating scenarios. Process simulations are an excellent tool for this work as any number of scenarios can be accurately evaluated using the calibrated model.

REFERENCES

1. Hydromantis (2001) GPS-X Technical Reference, Hamilton, Ontario
2. Hydromantis (2001) GPS-X Users Manual, Hamilton, Ontario
3. Boner, Mark, (2001), CSO Technology Performance and Applications : Using the Columbus Experience in Planning and Designing CSO and Stormwater Control Facilities, WEFTEC 20001 Seminar #115, Atlanta, Georgia
4. Burford, Frank (2002) Woodward Avenue WWTP Headworks Replacement, A Unique Design/Build Project, WEAO 2002 Annual Technical Symposium, Hamilton, Ontario